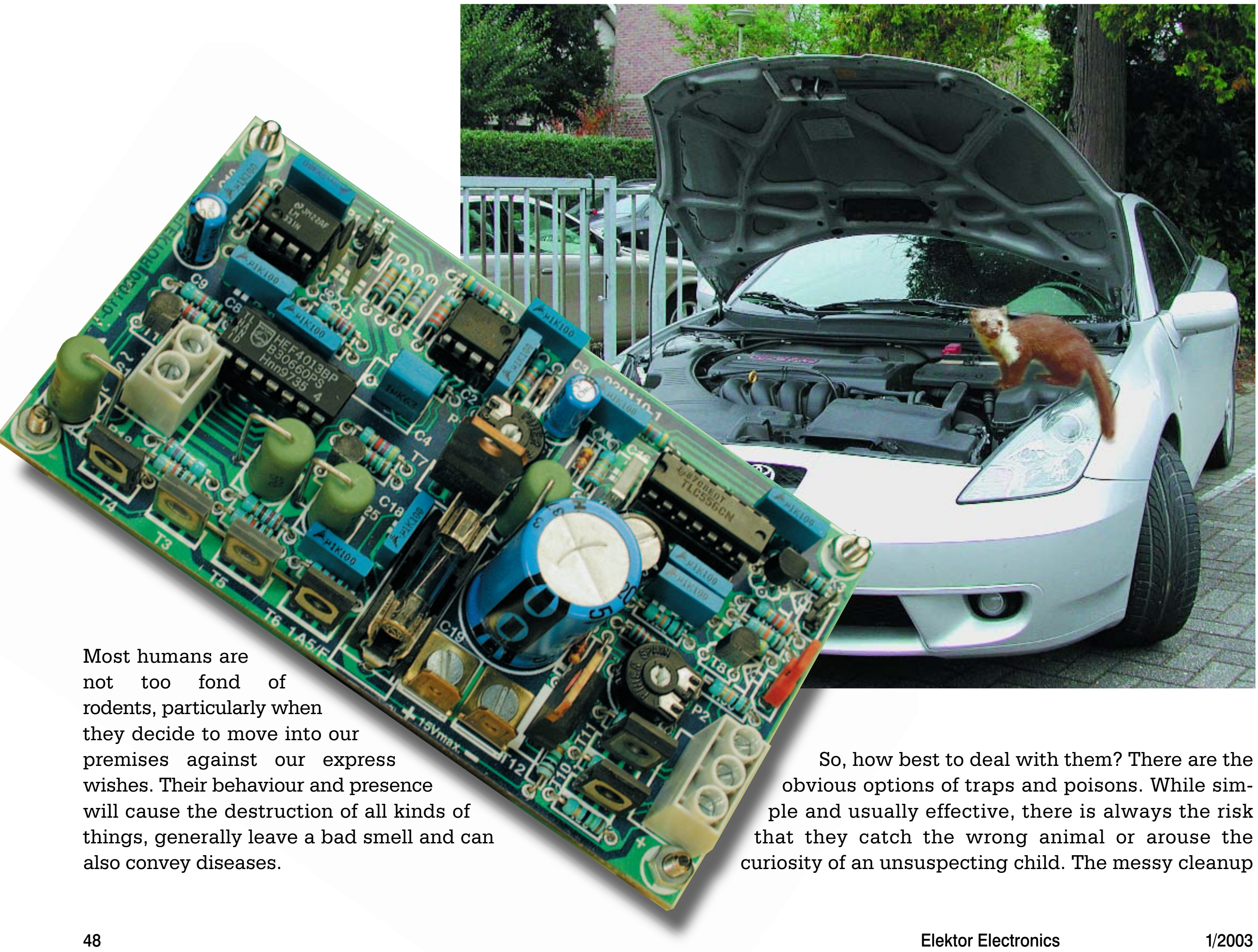
Rodent Deterrent

environmentally friendly and humane

Design by T. Giesberts

Mice, rats and even the playful and inquisitive marten are rodents that are certain to make a considerable nuisance of themselves whenever they interact with human activity. Their presence will result in unpleasant odours and irritating noises while their sharp teeth will cause havoc with rubbish bags, hoses, (car) electrical wiring and just about everything else. Therefore, suitable measures are in order and electronics can prove itself indispensable here.



Most humans are not too fond of rodents, particularly when they decide to move into our premises against our express wishes. Their behaviour and presence will cause the destruction of all kinds of things, generally leave a bad smell and can also convey diseases.

So, how best to deal with them? There are the obvious options of traps and poisons. While simple and usually effective, there is always the risk that they catch the wrong animal or arouse the curiosity of an unsuspecting child. The messy cleanup

Main Features

Power supply voltage	9 to 15 V max.
Current consumption (1 tweeter PH8)	400 mA (output on)
Max. current consumption (4 PH8 in parallel)	900 mA (output on)
Standby-current (K2 open)	< 1 mA
Duty cycle	1 min. every 4 min.
Output frequency	19 to 38 kHz
Output frequency (JP1 fitted)	9.5 to 19 kHz
Sweep-frequency	2 to 19 Hz
LED blink frequency	3 Hz
LED current	6 to 40 mA
LL-input	> 2.5 V
OC-input	< 1 mA (≈15 V/15 kΩ max.)

afterwards is not something to look forward to either. Sometimes the rodent in question is actually a protected species, so that killing is not an option that is available in that case. Fortunately there is quite an effective, much more animal-friendly and far less messy way to keep rodents at bay.

A device that produces a reasonably strong acoustic signal with a frequency just above the range of human hearing is perceived as very unpleasant, if not painful, to rodents. After a while they will be persuaded to look elsewhere for food and lodgings.

Concept

An electronic rodent deterrent based on ultra-sound is not only an effective and environmentally friendly way of solving this nuisance, the design and construction of such a device is also something that is an entirely appropriate subject for us.

What are the design elements of the device that we present here?

We started with a voltage-controlled oscillator (VCO), which is modulated with the aid of a second oscillator in such a way that it produces a continually varying output signal between 19 kHz and 38 kHz. Of course it would have been possible to operate the oscillator at one fixed frequency. However, since we do not know exactly which frequencies rodents dislike most, we made the generated tone cover the entire relevant frequency range. The output signal is amplified considerably and converted into a strong acoustic signal by a piezo tweeter. The end result is an ear splitting noise level of around 105 to 110 dB. This is unbearable for an animal that can hear these frequencies. The final amplifier stage has been designed so that it can drive up to four piezo tweeters in parallel — this is useful, for example. if you would like to cover all the corners of an attic simultaneously.

Generating such a high sound pressure requires a reasonable amount of current, of course. In order to allow for the possibility of powering the circuit from a car battery, we have limited the current consumption by not running the circuit continuously, but switching it off and on periodically: 1 minute on, 3 minutes off. This will prevent a battery from being drained in less than a day.

Finally, as an optional additional feature, it is possible to extend the circuit with an ‘optical deterrent’ consisting of a couple of bright flashing LEDs — all this to make the life of the rodents really as unpleasant as possible in and around our homes, under the engine hood of our cars, etc.

Practical implementation

The schematic, with all the various details worked out, is shown in **Figure 1**. The VCO comes in the from of IC2, an LM331. This IC requires only a small number of external components and can be used to generate square wave signals with frequencies ranging from 1 Hz to 100 kHz. The components that determine the frequency of IC2 are R8, R9, R10, C6 (+C7) and C8.

The control signal that modulates the frequency of the VCO is applied to pin 7 and is generated by a square/triangle oscillator comprising IC1a and IC1b. This supplies a triangular output voltage, the amplitude of which varies from about 3 to 5 V. The speed at which the modulation takes place (the sweep frequency) can be adjusted with P1 between 2 Hz and 19 Hz. It is possible that the effect of the circuit on the rodents may be influenced somewhat with this adjustment.

All the components around the VCO and square-triangle oscillator are dimensioned such that the final generated frequency varies from 19 to 38 kHz. In order to be able to test the circuit by ear and check that it actually produces a signal, the oscillator frequency can be reduced by an octave by temporarily closing jumper JP1. **Stand clear** — humans can now also hear the output frequency!

Because the duty cycle of the output signal of the LM331 is not constant, a divide-by-two (IC3a) follows the LM331. As a consequence, the duty cycle is always 50%, independent of the frequency. Adding the divide-by-two obviously requires the VCO frequency to be raised by a factor of two: IC2, therefore, actually varies from 38 to 76 kHz.

When designing the output amplifier that drives the piezo tweeter, achieving the highest possible output voltage across loudspeaker LS1 was the prime consideration. In order to realise this, a simple bridge amplifier was chosen, where the final stage transistor pairs T3/T6 and T4/T5 conduct alternately. Although the final stage appears a little unconventional, the operation is actually quite straightforward: T3 and T4 make use of a common base resistor (R18) to come into conduction. T1 and T2 alternately switch off T3 and T4. The values of voltage divider R14/R13 and R15/R16 were selected on the break-before-make principle. The instant the output of IC3a reaches half the supply voltage, both T1 and T2 are on. This way, we prevent both T3 and T4 from conducting at the same time. As a result, it is possible to remove IC3 (if that should ever become necessary) without causing any short circuit currents. The common outputs of T3 and T4 drive T5 and T6, so that either T3 and T6 conduct simultaneously, or T4 and T5.

In order to prevent a short-circuit between T5 and T6 in the simplest possible way, a power resistor (R22/R25) has been added in the collector circuit to limit the current. The added advantage of this measure is that the output stage is now short-circuit proof (for a short period only, otherwise R22 and R25 will go up in smoke). A third advantage of the output resistors is that the current peaks through

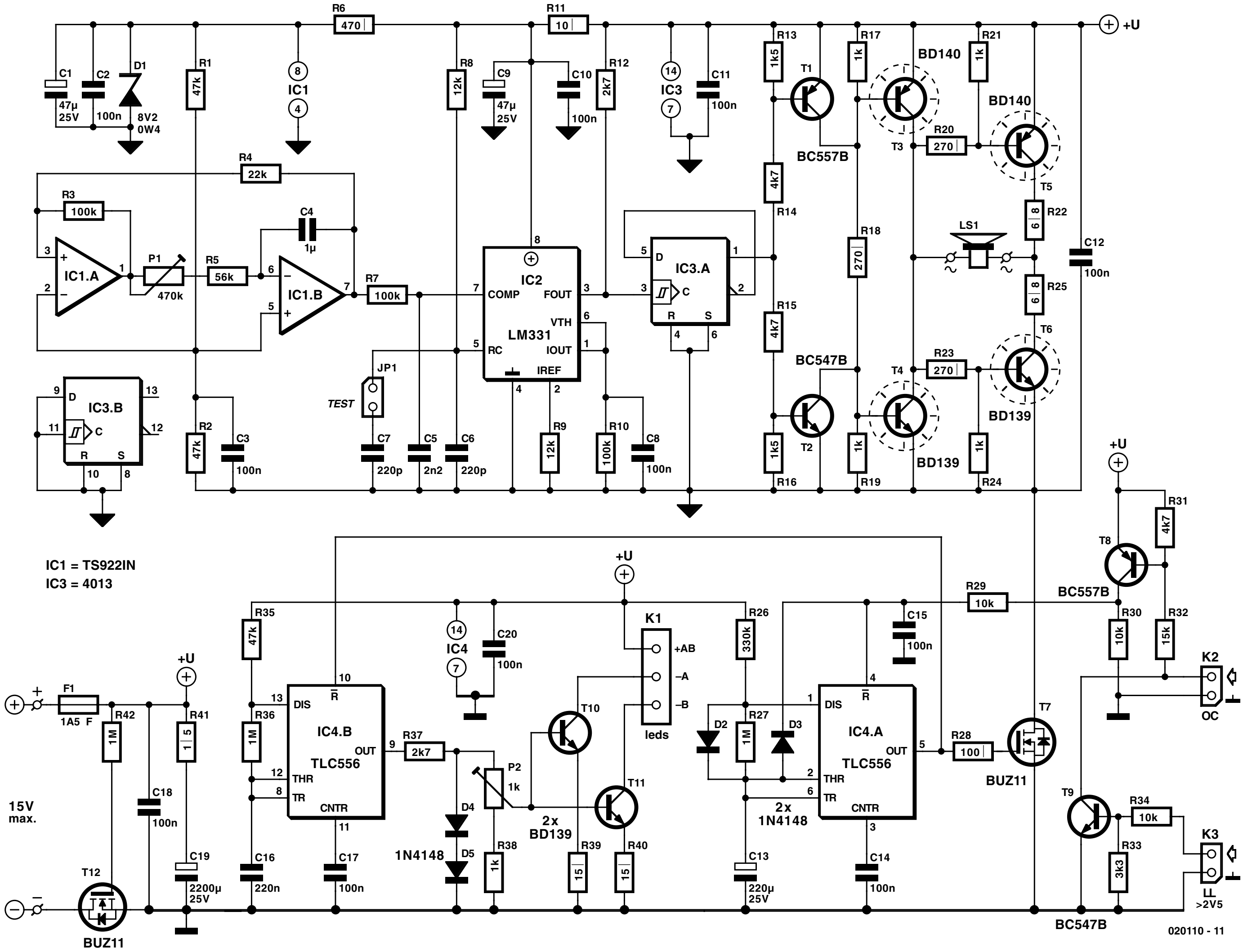


Figure 1. The complete schematic of the rodent deterrent. The top part of the schematic is responsible for the actual sound generation.

the capacitive load of the piezo tweeter(s) are limited, something that will improve the life expectancy of the tweeter(s).

Although it is possible (in principle) to use other makes and types, for the prototype we used a piezo tweeter model PH8 from Visaton for LS1. This tweeter has a small horn and produces a sound pressure level of 96 dB at an input power of 1 W. Since the output amplifier delivers about 20 W, you can work out for yourself what impressive number of decibels our rodent deterrent produces. It is very fortunate that the generated signal is outside our own hearing range…

Extra features

The energy saving feature implemented by periodically switching the generated ultrasonic signal on and off has been realised with the aid of a 556 (IC4a) configured as an astable multivibrator. During the 'high-time' of the output of IC4a (pin 5), T7 will conduct and IC1, IC2, IC3 and the output amplifier are powered. During the 'low-time' of IC4a, T7 will block and the ground connection to the oscillator and amplifier sections is interrupted. In order to minimise the voltage drop while generating the acoustic signal, a power-MOSFET type BUZ11 was selected for T7. This MOSFET has a very low on resistance (typical $R_{DSON} = 0.04\ \Omega$).

In order to make the circuit as versatile as possible, there is also the provision to drive timer IC4a with an external signal (from a passive infrared motion sensor, for example). The circuit can be activated via T8 with an open-collector output (OC, K2). T9 has been added for the eventuality that only a logic level (LL, K3) is available (> 2.5 V). When T8 is not active, R29 and R30 hold the reset input of IC4a low. Diode D3 has been added to prevent an active output from being muted.

Depending on the amount of charge in C13, it can sometimes take a little longer before IC4a enters the reset state. Another nice feature occurs when the output is not active: at that time, C13 will be discharged by R27. But when T8 turns off, C13 will discharge quicker and the voltage will be below the input threshold of IC4a, causing the output to turn on for a few seconds before resetting.

Finally, the previously mentioned 'optical extra'. This has been realised with a second timer (IC4b), configured as an oscillator. The oscillator, via two current sources (T10, T11), causes two LEDs connected to K1 to flash at a frequency of about 3 Hz. Because the reference (D4, D5) of the current sources is adjustable with P2, the LED current can be varied from about 6 mA to 40 mA. Make sure that both current sources are loaded, otherwise the unloaded transistor will cut off the reference voltage to the other one. If desired, both outputs can be connected in parallel so that the output current can be doubled (1 × 80 mA). For the indicator we have superbright LEDs in mind, such as the devices from Sharp listed in the parts list (available from, among others, Conrad Electronics). Depending on the power supply voltage, a number of LEDs can be placed in series. The superbright types tend to have a typical forward voltage drop of around 2.5 V that means that at 12 V, four can be connected in series, and five at 15 V. The anodes of both chains are connected to the common connection +AB, the cathode for each chain has its own separate connection: –A and –B.

Power supply

The power supply for the rodent deterrent can take the form of a 12-V battery or a separate mains adapter with an output voltage of 9 to 15 V. The output voltage needs to be regulated, while the adapter also has to be able to deliver a considerable amount of current. The current consumption of the circuit typically amounts to about 400 mA during the period when the output signal is active. When four piezo tweeters are connected in parallel the current can increase to 900 mA!

Fuse F1 protects against short circuits, while MOSFET T12 provides protection against reversal of the power supply polarity. Compared to T7, it appears at first glance that the source and drain have been reversed. This is not so however. The channel is definitely conducting, independent of the fact that the current now flows from source to drain, because the gate voltage is positive with respect to the source. The inherent body diode of the MOSFET

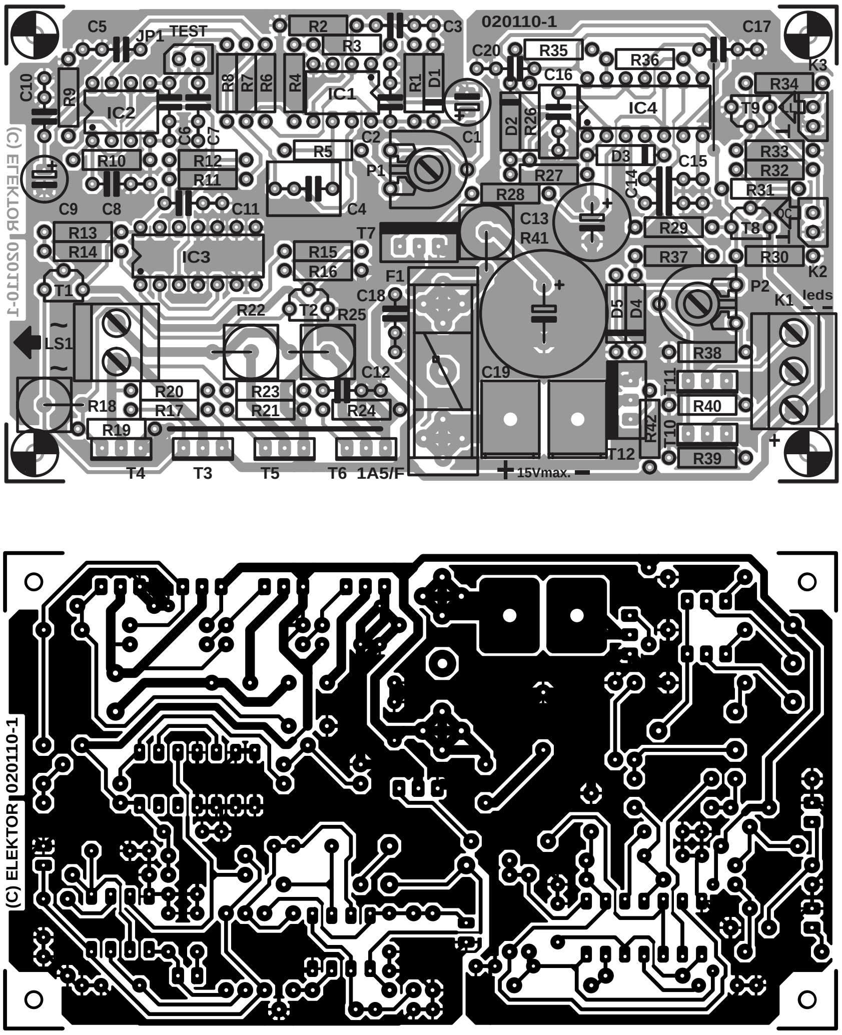


Figure 2. By designing a clever circuit layout, the number of wire links is limited to just two.

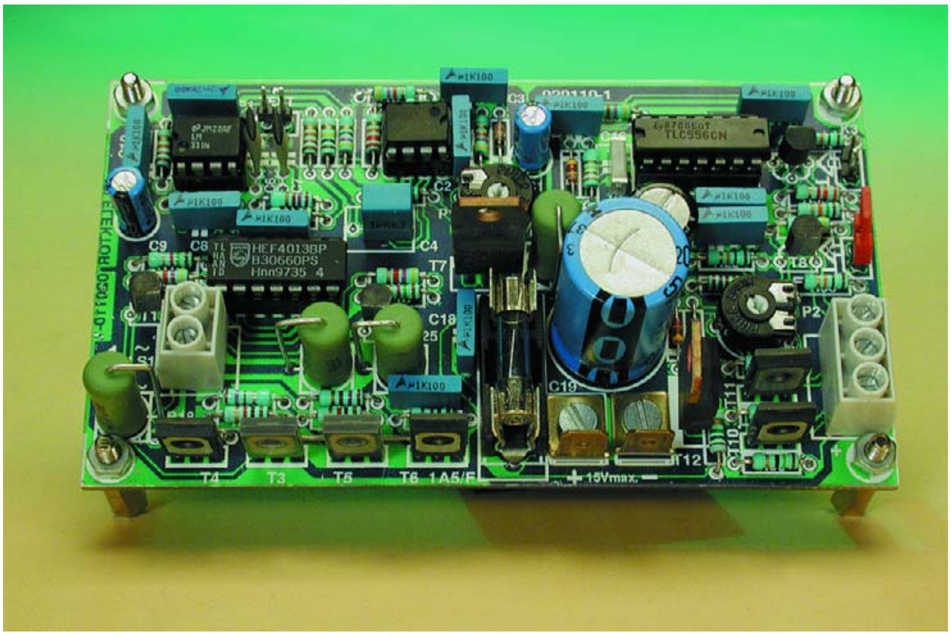


Figure 3. This is what a correctly assembled circuit board should look like. T3, T4, T5 and T6 need to be mounted on a heatsink.

is now connected in the forward direction. If the power supply voltage is applied the wrong way around, the gate voltage will be negative with respect to the source and the body diode will be blocking. This MOSFET prevents the voltage drop that is associated with the diode that is normally connected in series with the power supply.

Construction

A nice printed circuit board has been designed for the circuit, the layout and component overlay of which is shown in **Figure 2**. Despite the compact dimensions (it measures only 11 ? 6.5 cm), the construction is likely to occupy you for a few hours, because the PCB is quite densely populated with parts. Start with the lowest components (resistors, IC sockets), follow that with the taller parts (vertical resistors, transistors, electrolytic capacitors). Make sure not to forget the two wire links. It may actually be best to start with those; one is located next to T3, T4, T5 and T6 and the other to the right of IC4.

The external connections have been clearly marked, so there is very little opportunity for anything to go wrong. PCB screw terminals can be used for the loudspeaker and the LEDs (K1), while we used QC tabs, common in the automotive industry, for the power supply.

Even though the output transistors T3 through to T6 don't get very warm, it is still recommended to provide them with a small heatsink (a small piece of aluminium sheet will suffice). The transistors T3 to T6 have been placed at the edge of the PCB specifically for this purpose. The transistors need to be fastened to the heatsink with insulating washers.

For completeness sake we will mention that if you see no value in the optical signalling, the relevant components around IC4b, including T10, T11 and K1 can simply be omitted.

The choice of enclosure is completely up to you. There are many enclosures that are suitable for this PCB.

A final remark: if you are not going to use a proximity or motion detector then a jumper can be fitted in place of K2. The circuit will then simply oscillate on and off on its own accord.

(020110-1)

COMPONENTS LIST

Resistors:
R1,R2,R35 = 47kΩ
R3,R7,R10 = 100kΩ
R4 = 22kΩ
R5 = 56kΩ
R6 = 470Ω
R8,R9 = 12kΩ
R11 = 10Ω
R12,R37 = 2kΩ7
R13,R16 = 1kΩ5
R14,R15,R31 = 4kΩ7
R17,R19,R21,R24,R38 = 1kΩ
R18 = 270Ω 5W
R20,R23 = 270Ω
R22,R25 = 6Ω8 5W
R26 = 330kΩ
R27,R36,R42 = 1MΩ
R28 = 100Ω
R29,R30,R34 = 10kΩ
R32 = 15kΩ
R33 = 3kΩ3
R39,R40 = 15Ω
R41 = 1Ω5 5W
P1 = 470kΩ preset
P2 = 1Ω preset

Capacitors:
C1,C9 = 47µF 25V radial
C2,C3,C8,C10,C11,C12,C14,C15,C17,C18,C20 = 100nF
C4 = 1µF MKT (Siemens), lead pitch 5 or 7.5mm
C5 = 2nF2
C6,C7 = 220pF
C13 = 220µF 25V radial
C16 = 220nF
C19 = 2200µF 25V radial

Semiconductors:
D1 = 8V2 0.4W
D2-D5 = 1N4148
T1,T8 = BC557B
T2,T9 = BC547B
T3,T5 = BD140
T4,T6,T10,T11 = BD139
T7,T12 = BUZ11
IC1 = TS922IN ST (Farnell)
IC2 = LM331N
IC3 = 4013
IC4 = TLC556

Miscellaneous:
JP1 = 2-way pinheader with jumper
K1 = 3-way PCB terminal block, lead pitch 5mm
K2,K3 = 2-way pinheader
LS1 = 2-way PCB terminal bock, lead pitch 5mm
Piezo tweeter type PH8 (Visaton)
F1 = fuse, 1.5A, fast acting, with PCB mount fuse holder
High intensity LEDs (not on PCB), e.g., Sharp Super-luminosity LED Lamp type GL0ZS042B0S (Conrad Electronics # 18 30 08)
2 spade terminals, PCB mount using 3-mm bolts and nuts
PCB, order code **020110-1** (see Readers Services page)

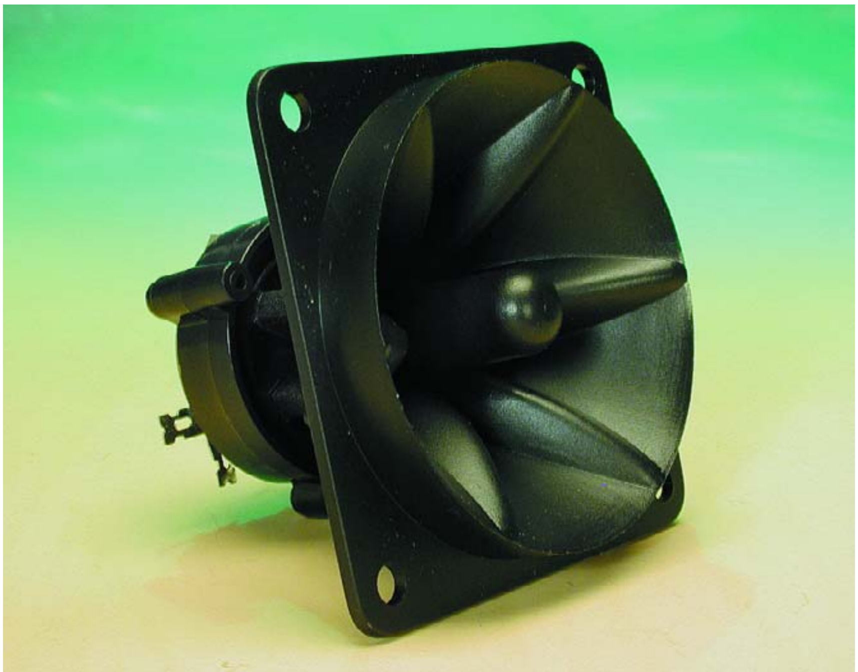


Figure 4. The piezo tweeter used for the prototype is a type PH8 from Visaton, it has a frequency range from 3 kHz to 40 kHz and is capable of producing very high sound pressure levels.